A NOVEL SENSOR TO MEASURE THE CONCENTRATION OF NITROUS OXIDE IN ANESTHETIC MIXTURES.

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Abstract - **This work describes experimental results of a novel intrinsic gas sensor, based on Plastic Optical Fiber (POF), to detect and to measure relative concentration of Nitrous Oxide in Oxygen in anesthetic mixtures. The sensor was able to measure concentrations from zero to 100 V%, in a total flow of 10 l/min, with sensitivity around –2.32 10^{-3} dB/V%.**
Keywords – Gas sensor, anesthetics, nitrous oxide, plastic optical fiber.

I. INTRODUCTION

Nitrous Oxide has been used as anesthetic since 1844. At present, it is a powerful coadjutant in inhalation anesthesia with halogenated agents. There are, at least, two good reasons to monitor nitrous oxide in the surgery rooms: to insure the patient safety and to avoid chronic environmental exposure of operating room personnel. Nitrous Oxide is usually administered to the patient during inhalation anesthesia at great concentrations and can turn easily a hypoxemic mixture. Headache, irritability, increased fatigability and emotional stress has been related to chronic exposure to anesthetics. Increased relative risk for congenital abnormalities was attributed, particularly, to the nitrous oxide. Therefore, monitoring the anesthetic delivery system provides information that improves the administration of anesthesia with regard to recognition of adverse effects and safety to patient and operating room team [1].

The optical technology is perfect to be used in the hostile atmosphere of the surgical rooms due to its EMI immunity. Plastic Optical Fibers (POF) are more appropriate for this purpose than silicon fibers for its robustness and easier manipulation.

The purpose of this study was to extend the results obtained in a previous work in which it has been demonstrated the possibility of using POFs as intrinsic sensors for anesthetic gases [2], starting with Nitrous Oxide (N_2O).

II. METODOLOGY

The sensor was built from a poli-metil-metacrilate (PMMA) POF manufactured by Mitsubishi Rayon Co. Those fibers have an optic attenuation around 0.14 dB/m @ 650 nm, are chemically and physically stable below 100° C and present small absorption of water as low as 5.2 g.cm/cm^2/h [3], which is a characteristic of PMMA polymer. The POF core has a refraction index of 1.492 and its cladding 1.417. To provide mechanical support to the sensor, a segment of POF was embedded in a block of polyester resin of 1 x 2 x 12 cm. After a period of 24 h, enough to cure the resin, the block face was polished until the exposure of the fiber core. In the body of the block of polyester it was placed the sensor head of an electronic thermometer.

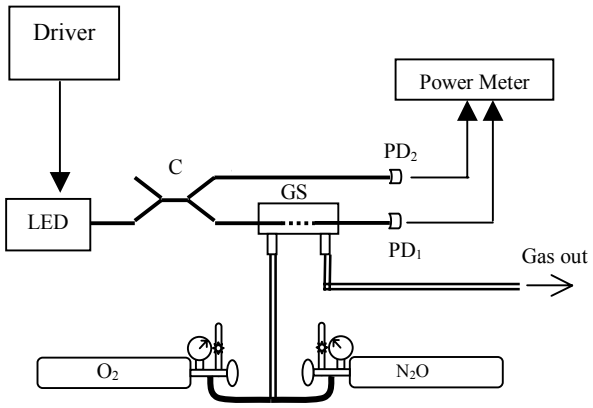

Figure 1.Optical setup of the gas sensor.

Electric wires	——	C	Optical fiber coupler
POF	▬▬	PD	Photodetector
Gas tubing	═══	GS	Gas sampler
Sensor	.....		

The schematic diagram of the experimental setup is shown in Figure 1. As light source we used three LEDs (480 nm, 660 nm and 950 nm). The radiation of the LED is launched into the optical coupler that divides the optical power in unequal portions. The major portion of the optical power is driven into the sensor; the other portion is used as a reference. The optical coupler was built in the same way as the sensor element: each side was built separated and then joined together by the aid of a shrinkable sleeve [3 - 4]. The light that arrives to the sensor element interacts with its surface and is modified in this interaction. Both the sensing and the reference light are detected by two silicon photodiodes connected to an optical power meter (OPM). The OPM amplifies the signals and divides one (from the

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Abstract

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sensor) by the other (the reference) in order to eliminate common-mode fluctuations.

A 16 cm by 2.8 cm copper cylinder accommodated the sensor and was used as gas sampling chamber.

Ultra-pure Oxygen, Nitrous Oxide, a stainless steel regulator valve without rubber parts for oxygen, a regulator valve for nitrous oxide, a flow meter for oxygen with maximum flow of 15 l/min and a flow meter for nitrous oxide for maximum flow of 15 l/min from AGA Healthcare S. A. were used. These were connected by latex tubing whereas the exhaustion of used gases was accomplished by a polyethylene tube.

After 45 min for stabilization of the electronic circuits, a continuous flow of pure oxygen was left to run through the system in order to wash out all the other gases. The oxygen and nitrous oxide were mixed as in a real surgery, using flow meters and pressure regulators. The first measurement was made for 10 liters per minute (l/min) of oxygen and none of N_2O, generating thus a mixture of 0 V% of N_2O in O_2. The next reading was for 9 l/min of O_2 and 1 l/min of N_2O (10V% of N_2O in O_2), and so on, until reaching 100 V% of N_2O.

III. RESULTS

The first measurement used a 660-nm LED and a sensor element measuring 50 mm in length. The temperature inside of the copper flask was 24.3 ± 1°C with total flow of 10 l/min of N_2O/O_2. The graph in Figure 2 shows the result of this experiment. The linear regression and standard deviation were respectively 0,996 and 0,00169. The sensitivity of this sensor was –2.32 x 10^{-3} dB/V%.

The graph in Figure 3 shows the result of another experiment that intend to verify the relationship between the wavelength of the light source and the sensitivity of the sensor. This assembly used LEDs with three different central wavelengths: 470 nm, 660 nm and 950 nm.

IV. DISCUSSION

It was already known the usefulness of POFs to detect the presence of substances whose refraction index lies between those from the core and the cladding [5 - 6]. Therefore, the most important point of this study was to demonstrate the possibility of measuring a refraction indexe close to 1, that is, smaller than that of the cladding.

Figure 2 demonstrates clearly that the sensor was able to discriminate different concentrations of the gases in experimental analysis. It can be noticed the good correlation between the points of the graph. The sensor sensitivity was –2.32 10-3 dB/V%. The response of the system was fast and the necessary time for the system to reach a stabilized reading was approximately 10 s.

Another issue investigated in this work was the influence of the wavelength in the sensitivity of the sensor. The graph that represents the results of this experiment is shown in Figure 3. The comparison shows that the sensitivity of the sensor, when used radiation of 470 nm, was 38% larger

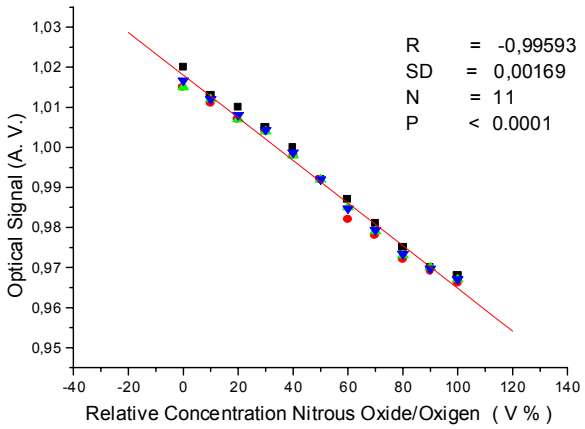

Figure 2. Optical response of the sensor as a function of the relative concentration of N_2O / O_2

than when used the radiation of 660 nm and 125% larger than when used the radiation of 950 nm. However, it should be considered another experimental data that concerns the stability of the sign. Notice that the sensitivity is larger for smaller wavelengths. In fact the sensitivity for 470 nm was 38% larger than that for 660 nm and 125% larger than that for 950 nm. However, the stability of the system is poorer and the signal noisier for 480 nm than for 950 nm in which case the output signal was very stable and noiseless.

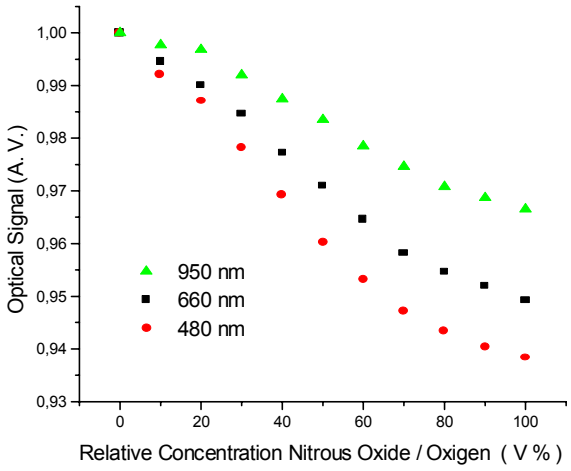

Figure 3. Optical response of the sensor as a function of the relative concentration N_2O/O_2 for three different wavelengths

It is now necessary to explain the phenomenon involved with the sensitivity of the sensor for different wavelengths.

When we grind the POF for fabricating the sensor, we add microrugosities in the polished surface and its dimensions vary with the grit size of the sandpaper used. Some of the scratches are of the same order of magnitude as the wavelength of the light. The Mie scattering theory shows that for targets smaller than the wavelength, the light scattering is inversely proportional to the fourth power the wavelength. Then, for larger wavelengths (950 nm), the light radiation is less affected by the surface rugosity than for smaller wavelengths (480 nm). Therefore larger wavelengths are less dispersed and the measured optical power is larger and more constant. When smaller wavelengths are used, the resulting scattering is larger, reducing the optical power measured by the photodetector.

At the time of writing, we were still investigating the phenomena that can be involved in the operation of this sensor. Some of the possibilities considered by us, still under research, are: chemical or physical interaction of the gas (sample) with the core material (PMMA), alteration of the geometry of the core by polishing and the formation of liquid film induced on the sensor surface.

V. CONCLUSIONS

The sensor described was capable to detect and discriminate anesthetic mixtures of nitrous oxide in oxygen in concentrations varying from 0V% to 100V%, covering, therefore, the clinical range (25V% to 75V%) for inhalant anesthesia. The complete characterization of this sensor also includes its sensitivity to temperature, pressure and humidity. Given the importance of the halogenated anesthetics in the practice of anesthesia, we will also test halothane, enflurane, isoflurane and sevoflurane on our sensor in a continuation of this study.

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